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Copper mining in South America

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COPPER MINING IN SOUTH AMERICA

by

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A

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LOCATION:

The Morococha district is situated in the Andes of Central Peru, Department of Junin, four miles east of the crest of the Western Cordillera, which there forms the Continental Divide. The town of Morococha is at an elevation of 14,800 feet and is connected by rail with Callao, the port of Lima, ninety miles to the west , and with La Oroya, the smelting center, thirteen miles to the east. The Peruvian Central Railway ascends from Lima along the valley of the Rio Rimac to Ticlio (15,665 feet) where it tunnels through the Divide and descends the Yauli Valley to La Oroya. From Ticlio, a branch line, crossing the Divide at La Cima (15,800 feet), enters Morococha from the west and continues through it to join the main line again at Cut-Off, six miles to the south-east. (See map, page 1.)

TOPOGRAPHY:

The principal mines of the district occupy an area approximating five square miles surrounded by a zone of feebler mineralization. The mines lie in a country of great relief, the elevations of which vary from 17,300 feet at Nanacinga Mountain on the western edge of the district, to 14,300 feet at Huascracocha Lake on the east. The major topographic feature is an east-trending valley containing three lakes at different elevations and surrounded by towering peaks, most of which are over 16,000 feet. Several tributary valleys enter the principal one from the north and south, accentuating the roughness of the topography. The glacial, U-shaped character of the valleys and extensive ground moraines in their bottoms have been modified considerably by post-glacial stream erosion, and the accumulation of talus and alluvial fans.

This high, Andean country is completely barren of trees. Its slopes are covered with talus except where they are too precipitous to retain it and bare rocks are exposed. In the bottoms of the valleys and on the more gentle slopes immediately east of the mines, however, the ground supports an abundant growth of stiff, mountain grass, which affords pasturage for sheep and llamas.

CLIMATE:

Although Morococha lies almost at the crest of the Andes, its climate is relatively mild, since it is only ten degrees south of the equator. The year is marked by two seasons: six months (November to April, inclusive) during which there may be rain and hail, and six months of fair weather which corresponds to the winter season of the Southern Hemisphere. During the dry, winter season, the temperature is slightly lower than in the wet season, but exceedingly low temperatures are unknown. Due to the high day temperature of the sun, ice formed on the coldest nights rarely lasts after ten ô'clock in the morning. The diurnal variation in temperature from day to night and from sunlight to shade is greater than the seasonal variation, this latter being seldom more than fifteen degrees. The mean annual temperature approximates 50 degrees Fahrenheit.

The ground of the region is abundantly charged with water except where mine workings have drained it. The greatest run-off is during January and February when the precipitation is heaviest and the temperature lowest. Its flow is eastward into the Rio Yauli at Pachachaca and thence into the Rio Mantaro at La Oroya.

HISTORY:

Morococha is one of the oldest mining districts of Peru and was probably mined for silver before the Spanish Conquest, though less extensively than the mines at Cerro de Pasco. During the Spanish Colonial period and the first years of the Peruvian Republic (1535 - 1850 ?), there was little activity in the district, but at the end of that period, interest in the region increased by reason of the finding of richer ores (carrying as high as 50 per cent lead and 60 oz. silver) and the advent of the aggressive firm of Pflucker and Sons. The Pfluckers enjoyed practically a monopoly of the district until 1886 when the Monteros came in and planned developments on a larger scale. These developments, however, only partially materialized, since in the '90's the silver-lead ores declined in grade and value and have never since regained importance.

Rich copper ore, carrying from 15 per cent to 20 per cent copper, was discovered in the district in 1894. In that same year the Central Railway was completed as far as Yauli, only six miles to the south of Morococha, and with this increased accessibility of the district, the discovery and development of its copper resources have been rapid.

Copper production on a large scale, with silver as an important accessory, began in 1905-1906 with the entries of the Morococha Mining Company and the Cia. Backus y Johnston del Peru. These companies bought many of the already numerous copper mines and thus, in a measure, consolidated the ownership of the district. At present, the Cerro de Pasco Copper Corporation, which controls both of the aforementioned companies, is the only large-scale operator in the district. There are, however, several small Peruvian companies in operation, but their total production scarcely equals one-tenth of the output of the district.

GEOLOGY:

The Morococha district offers to the geologist exceptional opportunities for studying the problems of ore deposition. The country rock is limestone, probably of Jurassic Age, although this has not been definitely determined. Commonly, it shows bedding and, although occasionally slightly shaley, is for the most part quite pure except where rendered siliceous near igneous contacts.

The formation has been intruded by quartz monzonite, diorite and a series of later rocks known as the Catalina Volcanics which are mainly rhyolite and andesite. Structures in these formations do not seem to be complex, although there has been considerable folding in the limestone.

Ore bodies have been formed near the igneous contacts. These consist of limestone replacements, mantos and veins in the limestone and in the Catalina Volcanics. To a minor extent, mantos are found in the quartz monzonite. It was long after the commencement of mining operations that ore was found to occur in the Catalina Volcanics. The veins in this formation are poor or barren at the immediate surface and good ore was only discovered by underground exploration.

The principal ore minerals are enargite, tetrahedrite, chalcopyrite and minor chalcocite, covellite and galena. Pyrite and sphalerite are plentiful, but at present the zinc is not reoovered. Although the mine run or ore contains considerable silver (perhaps an average of ten ounces per ton) there are no known prominent silver minerals. The sphalerite and galena are probably argentiferous, and silver replaces part of the antimony in the tetrahedrite (freibergite). Quartz is the common gengue mineral along with calcite, dolomite, rhodochrosite, gypsum and fluorite. The veins often show banding, especially in the more quartzose phases, with pyrite near the walls and the ore minerals toward the middle. Sphalerite is sometimes seen as a narrow band on one or both walls, and galena is often found in the same manner. With increase in zinc content, veins usually become leaner in copper with an increase in the percentage of silver. The best silver-bearing ore, however, is enargite (not mentioned above).

MINE:

The Morococha mine is divided into three main sections, viz: San Francisco, Gertrudis and Natividad. Each section has a separate shaft. In times past, there was a fourth section called Central, but at present this is included with the San Francisco section, giving an extra shaft and hoist there. San Francisco and Gertrudis sections both use a fifth shaft called Amistad, which is used for hoisting ore only, and at the collar of which is located the mill. The depth of this shaft is but 750 feet, which causes San Francisco and Gertrudis to hoist in cars all ore from the 1,000-foot level, at present the maximum depth of the mine. The Natividad shaft is 1,700 feet deep, and quite an extensive development program is being carried out there. The plan is to sink Central and Gertrudis shafts down to this level, and ten-inch shot-drill holes have been put down from the sumps of the two shafts.

The mine is quite wet, but the topography of the country takes care of that. A mile-long adit on the 400-level drains all workings above, while an adit six miles long on the 1,700-level drains all workings between the 400- and 1,700-levels. These adits result in a considerable saving in trouble and expense, for pumping is dispensed with.

The Natividad section, to date, is restricted to development work and produces approximately fifty tons of ore per day. The work in this section consists of drifting, raising under the two respective shafts and crosscutting to pick up the geologists' projections of principal veins. In the 1,700-level drainage adit, there are two small, rich silver veins being worked. This ore is shipped direct to the smelter at La Oroya. The future ore from this section (1,000-level to 1,700-level) will be milled at the portal of the adit. The camp at the portal, Mahr, is also the terminus of an aerial tramway from the mine at San Cristobal, another Cerro de Pasco project.

<u>SAN FRANCISCO SECTION</u>:

This is the largest section of the mine, both in extent and in production. There are three main productive levels: the 400, the 750 and the 1,000. Above the 400 there are levels at 50, 133 and 266 feet.

An adit on the 50-level runs to the machine shop, but at present this is used only to facilitate the handling of cars, etc., requiring repairs.

The 133-level is used for a waste re-tram level. All waste from the 1,000-level is hoisted in one-ton cars and dumped in waste chutes to fill stopes between the 400- and 750-levels. In this immediate section, the 133-level is the upper limit of stoping, for above lies Morococha Lake. This lake is of glacial origin, and it therefore has a bottom of glacial till with a silt and mud covering. All mill tailings are dumped into this lake in the hope of replacing the mud so that at some future time the ore above the 133-level can be mined with no consequent flooding of the mine as was the case in 1928. In this year, a cave-in brought down a section of the lake, filling the mine with mud. The three main veins in the San Francisco section strike across the lake, and some of the richest ore in the mine is encountered at this upper level. The veins average 10 per cent copper and 18 ounces of silver over a width of approximately 2,500 feet, and the safety cap left in the mine is 40 feet.

Between the 266- and 400-levels are two ore chutes. All ore from the 1,000-level is dumped here after being hoisted in one-ton square cars. On the 400-level it is loaded into three-ton Granby-type cars and hauled to Amistad shaft. The fact that Amistad shaft is only 750 feet deep results in this extra handling. Amistad dumps directly into the mill bins. Surface haulage has its drawbacks due to a difference in elevation of 150 feet between the collars of San Francisco and Amistad shafts in a distance of less than a quarter of a mile. The lake would have to be crossed and considerable fill made.

Central shaft, which is part of San Francisco section, is a four-compartment shaft, two compartments of which are devoted to skips and are only 800 feet deep. The remaining two compartments are 1,000 feet deep. This shaft is also located on the opposite side of the lake from the mill. It is in a section of very heavy ground, and constant repairs are necessary to keep it in operation. At present, it is used for materials, handling all steel and timber in addition to the excess waste from the 400- and 750-levels. On the surface, the lumber yard and blacksmith shop lie adjacent to this shaft.

The ore in San Francisco section occurs principally in narrow veins. These are mined by inclined cut and fill stopes. After drifting development work is finished, raises are run at 150-foot intervals from one level to another (levels being 250 feet apart) and sets are stood on the sill or main haulage level. The 400-level uses two types of cars, two-ton and three-ton Granbys, neither having the automatic dump. Therefore, the sets used on the 400-level are larger than those used on the 750- and 1,000-levels where the cars are two-ton square side-dump and one-ton end-dump. The sets are five feet center to center and lagged over with boards 2 inches by 12 inches by 5 feet, with a mat of old pipe, rails and timber laid on top. The back is then raised and a rill formed 75 feet each way from the raise, which then serves as a waste pass. The stopes are carried up by taking approximately 12-foot cuts, then filling. The chutes are cribbed with half-round eucalyptus and lagged with 2-inch by 12-inch by 5-foot boards. These are raised with each cut before filling. The bottoms of the rills are left rough, with no lagging laid down. This causes a considerable amount of good ore to be lost in the fines and also necessitates mucking the rills down by hand. When the stope reaches 100 feet and over, trouble is encountered with the chutes, since they are empty, and the muck in falling this distance causes great wear on the timber. Replacing worn lagging and broken cribbing is not only a difficult task, but a very expensive one.

This section of the mine is run on a contract system. A native is given a certain section as his contract, and he is directly in charge of all development, stoping, timbering and cleaning up. He is paid a certain amount per foot of development(depending on the rock, size of drift or raise, etc.) and so much per ton for all ore over 5-per-cent grade of copper. The company gives no assays on silver content of the ore and thus avoids paying tax to the Peruvian government on export silver. Silver is shipped in bullion copper to New York, where it is refined. The contractor is guaranteed a certain wage and is paid this wage, even though his particular section has no development and little ore for the month. He is responsible for all tools and buys the powder he uses. Air is furnished free. The company furnishes all timber and pays the men. By utilizing this system, a minimum of supervision is required. The personnel consists of one section foreman, two shift bosses and two native foremen. The mine works two shifts, night shift having a shift boss and a native foreman in charge. Each contractor has a "capataz," paid by the company, who is in charge of his contract during the night shift. A pipe and track crew is also on company account. The pipe men go where needed and each morning make all connections in the stopes and drifts. There are several crews, and each consists of one pipe man and a helper. It is generally 9:30 or 10:00 a.m. before the stopes are barred down, pipe connections made and drilling started. Main air lines are eight-inch, lead lines are two-inch and connections in stopes and drifts are one-inch pipe.

Each morning track crews and pipe crews go around putting rail to the face in each heading. Salvaging occupies the crews for the remainder of the day. The main haulage lines are of 30-pound rail, and development drifts are of 16-pound rail. There is considerable "copper water" in the mine and this, together with too long a usage of rails, results in expensive maintenance. Rails are used so long that the flanges on the car wheels cut off the heads of the bolts. The rails are also weakened by the action of the "copper water," which causes them to give way due to bending under the weight of loaded cars. The pipe crews have trouble with worn-out wrenches; lack of connections, tees and elbows and leaks caused by "copper water" eating holes in the pipe.

Improvements in San Francisco section would be effected by the following changes:

1. Using uniform timbering on main haulage levels and uniform cars through the section.

2. Lagging the bottoms of the stopes, which would save considerable fines in the ore and do away with hand mucking in the rills. (Eucalyptus timber is very cheap, and the cost of ripping would be small.)

3. Keeping the ore passes full and thus eliminating excessive wear on chute lagging, cribbing and chute lips due to falling ore.

4. Furnishing the machine men with plenty of steel. (Men in stopes drill all day with five to ten pieces of steel.)

5. Furnishing the men in stopes with pipe wrenches to enable them to make their own air and water connections.

6. Re-timbering or concreting Central shaft. This suggestion is made because Central shaft is in a very bad condition, and no amount of repairing will straighten the shaft and hold the heavy ground. Prior to sinking this shaft to the 1,700-level, as is planned, it should be put into the best possible condition.

7. The building of sanitary closets. This important improvement is one which would cost little and would make the mine a much healthier place in which to work. At present, old drifts and cross-cuts are used as retreats, as no other places are available.

GERTRUDIS SECTION:

This area was the first productive section of the mine, and the ore reserves are consequently nearing exhaustion. Much of the work is confined to cleaning up and scavenging stopes preparatory to abandonment. The present production here approximates 300 tons per day. This tonnage, until a few months ago, was assisted by 100-150 tons of high-grade ore from leased property. This lease has expired and, to date, has not been renewed. Formerly, the average grade of the section was about 8-per-cent copper, but it has now dropped to around 5-per-cent. Nearly all the tonnage is produced from square-set and fill stopes. A small tonnage comes from a nearly vertical vein in monzonite, mined by a combination of square-setting and cut-and-fill methods. The latter method is used in narrow parts of the vein. This vein is rather unique, due to the fact that the gangue is hard, white quartz containing grains of partially oxidized pyrite and veinlets of enargite, tetrahedrite and sphalerite. The silver assays are higher than the average ore of the mine. The width is variable, changing rapidly from one foot to seven or eight feet. The wall alteration is pronounced, and pyrite mineralization extends into the walls for some distance.

The other ore bodies of the section are irregular replacement mantos in limestone near monzonite contacts. The dip of the limestone is gentle, usually ten degrees to twenty degrees. Locally, the ore deposition has shown a decided preference for certain beds and is often cut off sharply by a bedding plane. An insufficiency of geological work has been done to determine whether certain beds are always barren, as at Rico, Leadville and other limestone replacement districts. The ore bodies are irregular both in horizontal and vertical extent. On one particular floor of a stope, the ore may be many sets wide, but one or two floors below or above, it will narrow to two or three sets. Chalcopyrite is the most important ore mineral in this section. The other principal minerals are enargite and tetrahedrite.

An irregular square-set system is in general use throughout the section. On each floor, a line of sets is run from ore pass to fill pass. Mining then starts at the ore pass, and a line of sets is run from wall to wall of the ore. This procedure is carried to the waste pass. A very irregular and unsystematic method is therefore developed, but, bad as the method is, it is not adhered to, and many stopes are a hodge-podge of sets.

Here, the same contract system is in operation as in San Francisco section, and the same problems present themselves.

MINE COSTS: 1936

The graphs presented on pages 18 - 25 give a complete and detailed account of all mine costs for the year 1935.

Graph No. 1 shows the cost per ton, by sections, the total mine cost, the average cost per ton for 1935, and the rates of exchange, by months, for the year.

Graph No. 2 gives the itemized costs per ton for each section, i.e., labor, lumber and explosives.

Graph No. 3 gives the cost per foot of development for sections, the total mine, and the averages for the year.

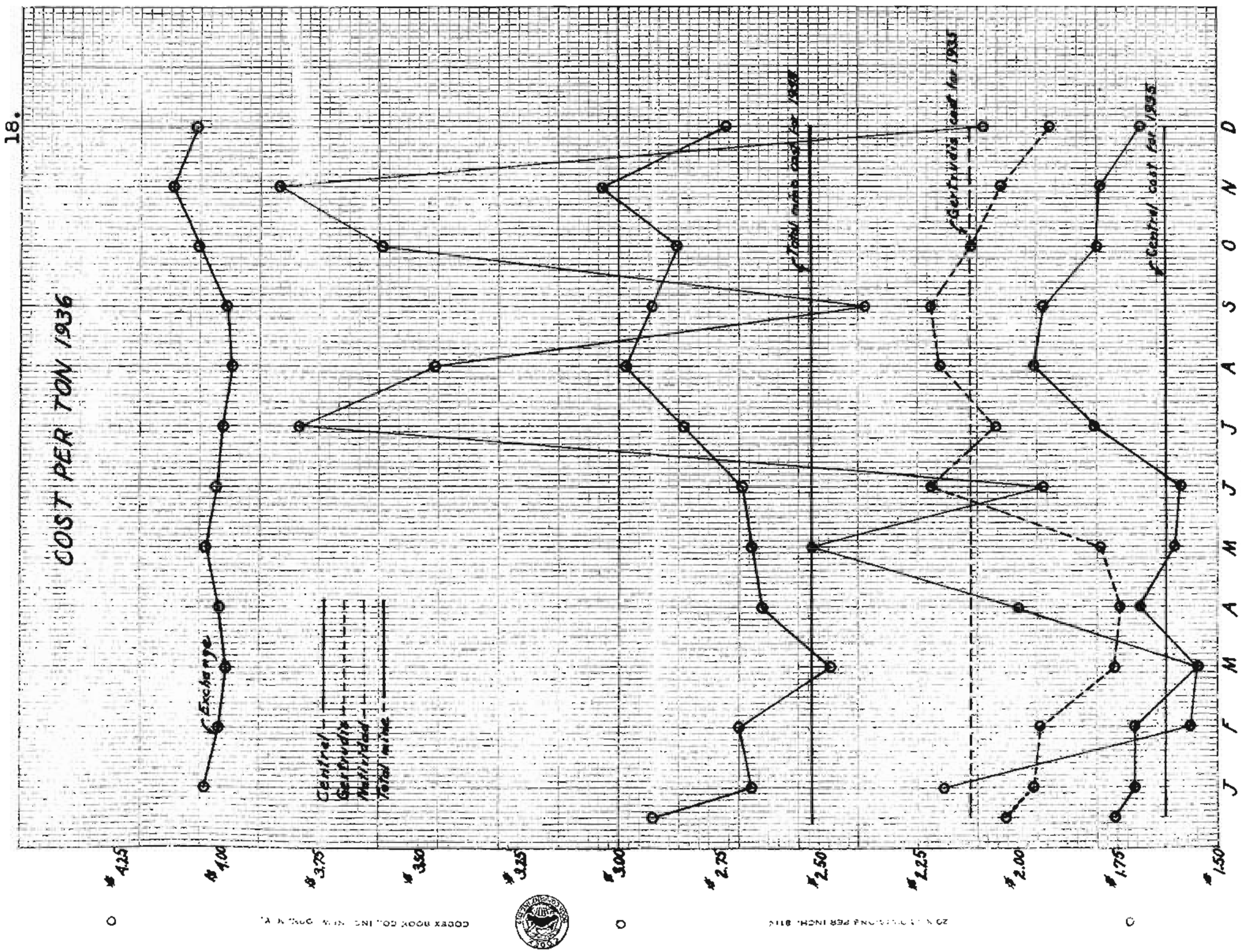
Graph No. 4 shows the development cost of drifts and cross cuts.

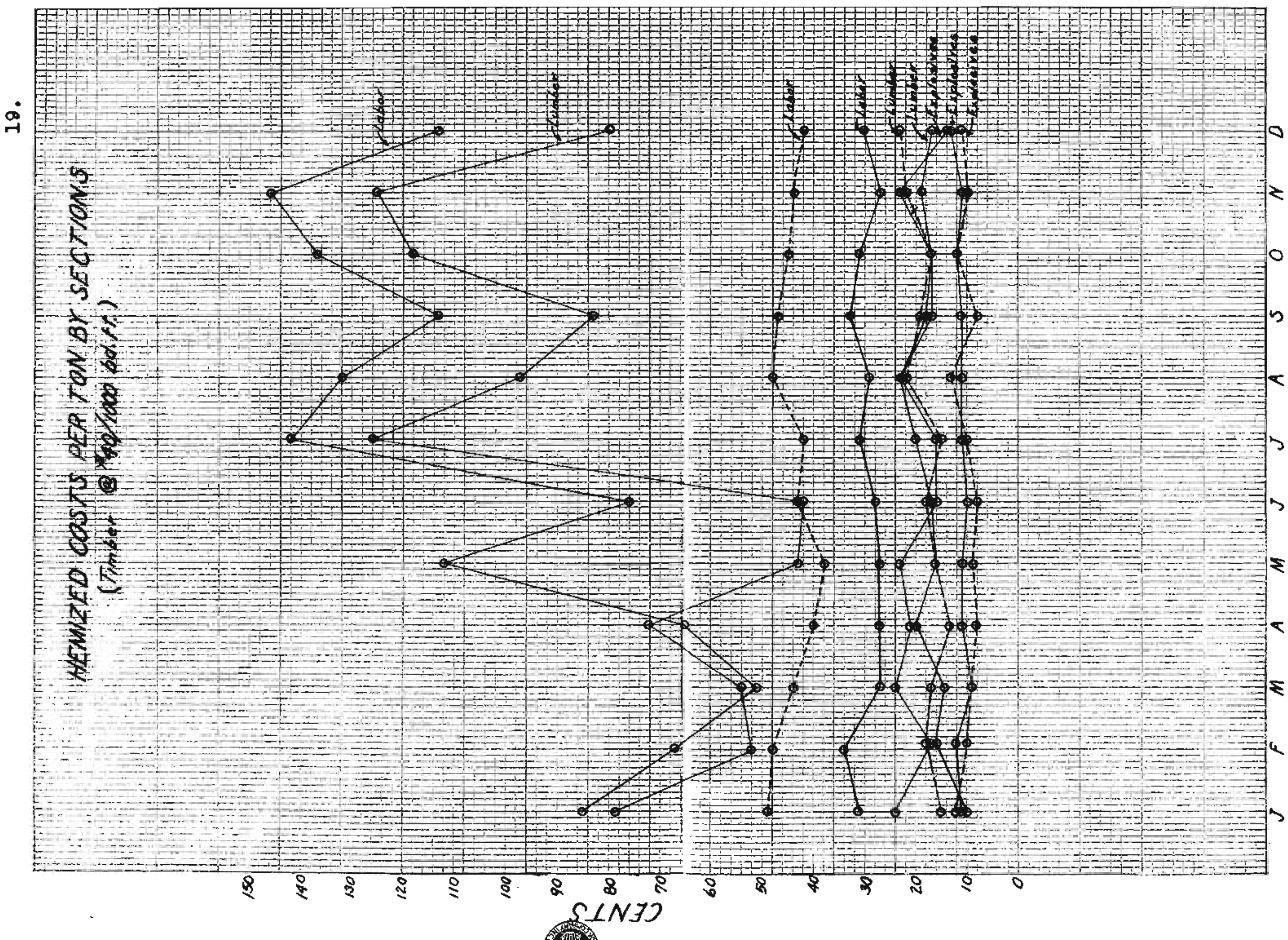
Graph No. 5 has the cost per foot of raises and winzes given for each section.

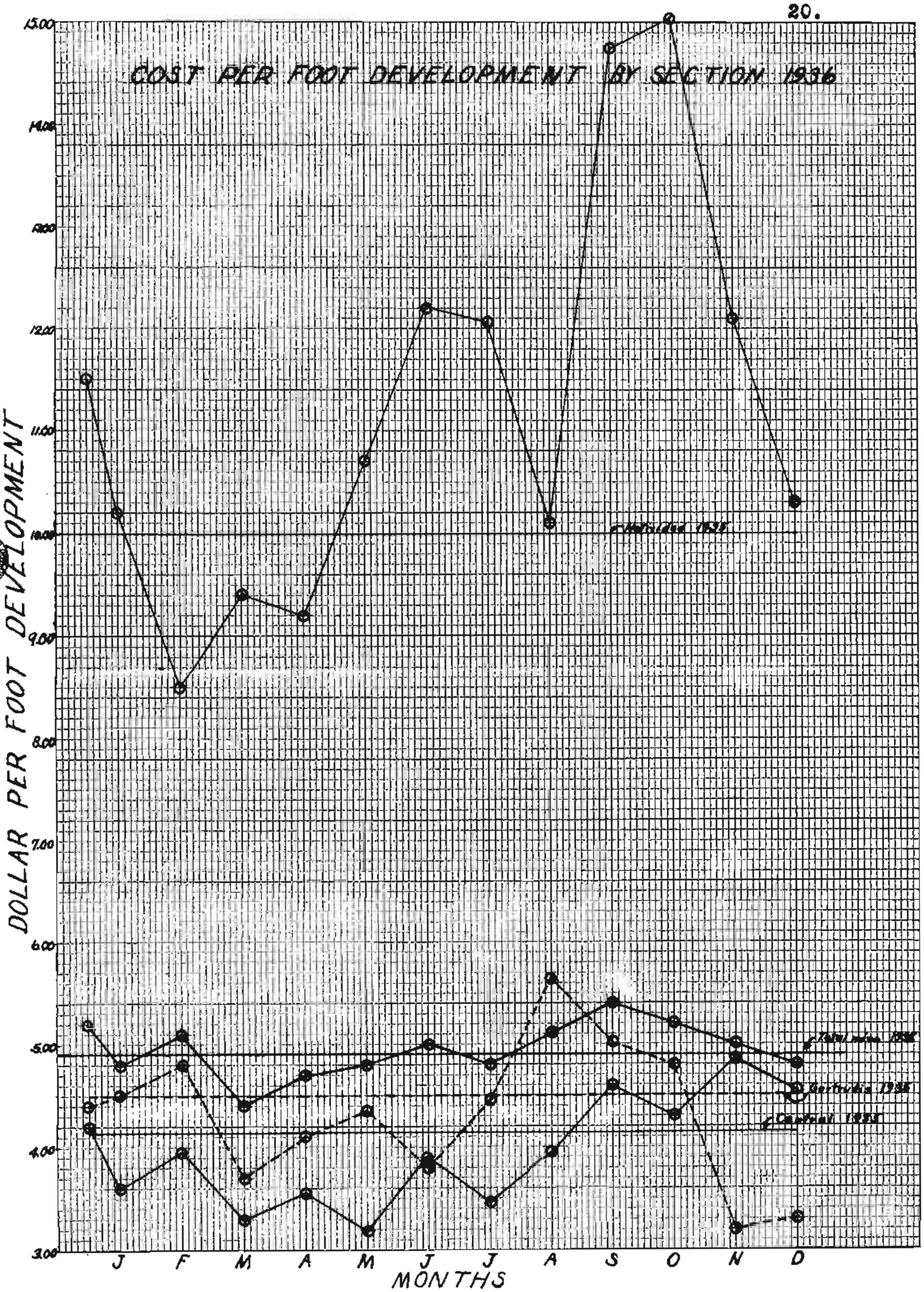
Graph No. 6 gives the tons per man shift for each section and also for the whole mine.

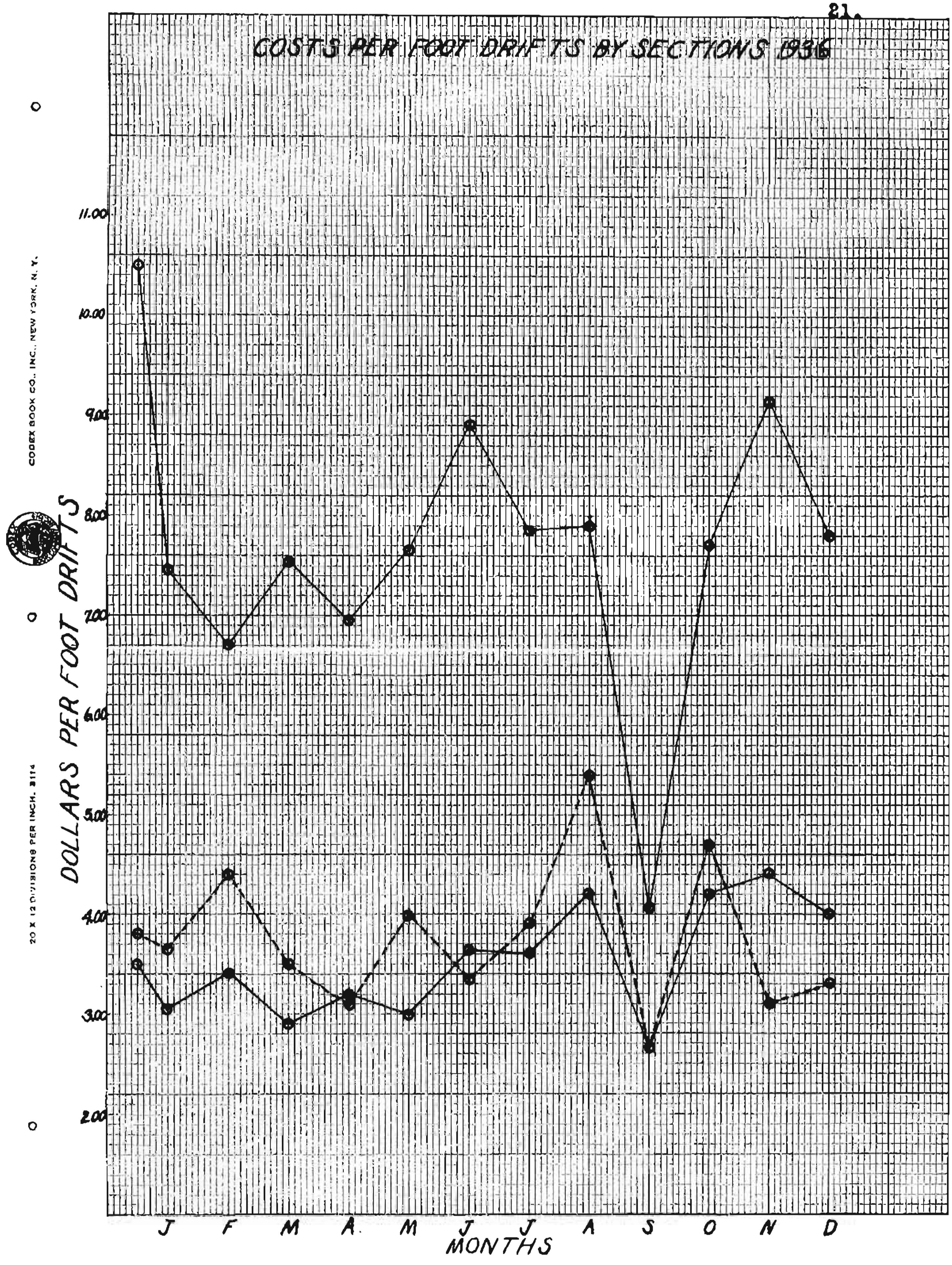
Graph No. 7 shows the average daily tonnages, by months, for each section, and the output of the whole mine.

Graph No. 8 shows the average daily grade of the ore in per cent of copper, by months, for the whole mine.

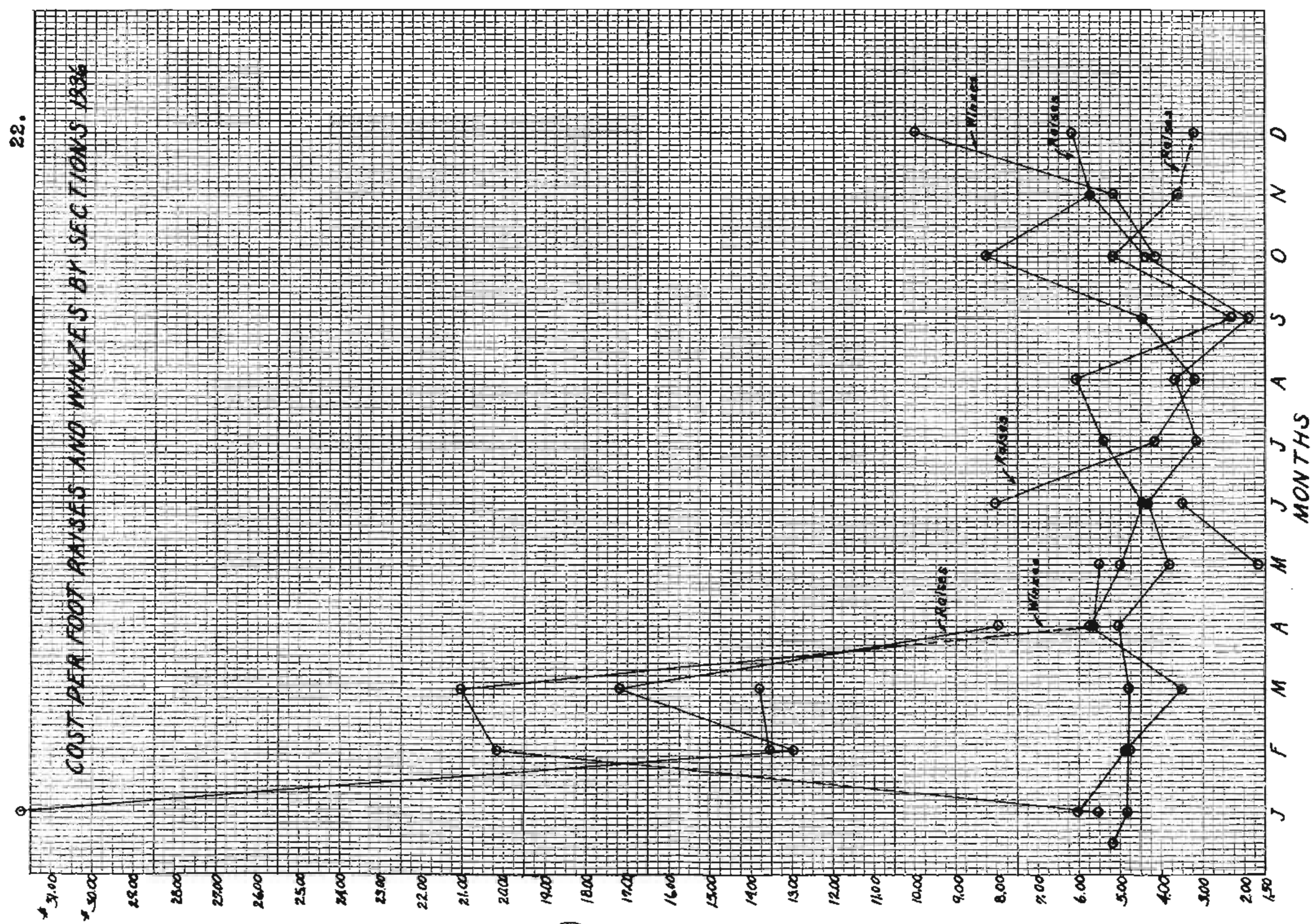

COST PER TON 1936
Exchange
Central
Gertrudis
Natividad
Total mine
Total mine cost for 1935
Gertrudis cost for 1935
Central cost for 1935
J
F
M
A
M
J
J
A
S
O
N
D
MONTHS
$ 4.25
$ 4.00
$ 3.75
$ 3.50
$ 3.25
$ 3.00
$ 2.75
$ 2.50
$ 2.25
$ 2.00
$ 1.75
$ 1.50

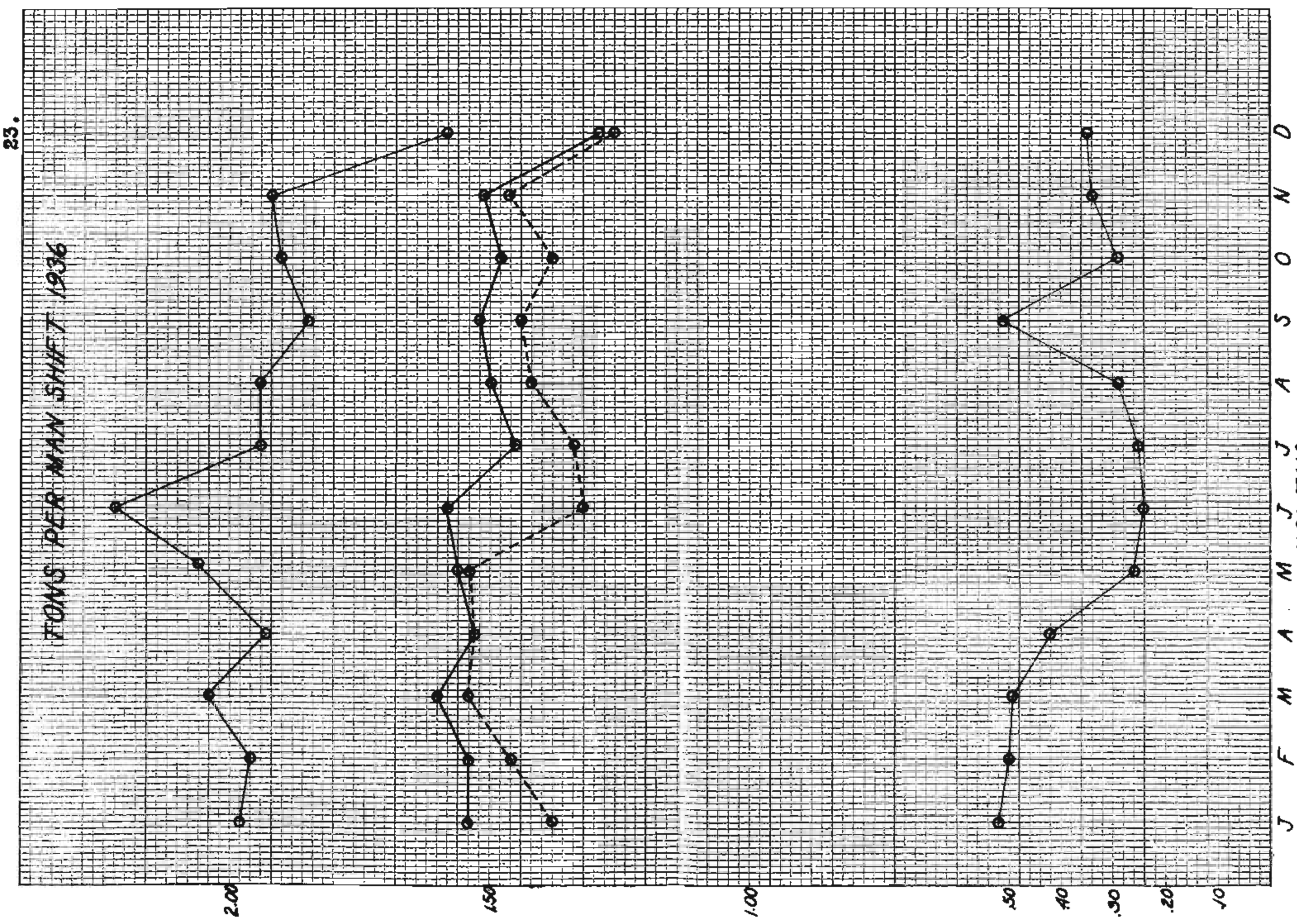

19.
ITEMIZED COSTS PER TON BY SECTIONS
(Timber @ $40/1000 bd. ft.)
Labor
Timber
Labor
Labor
Timber
Timber
Explosives
Explosives
Explosives
J F M A M J J A S O N D
MONTHS
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
CENTS

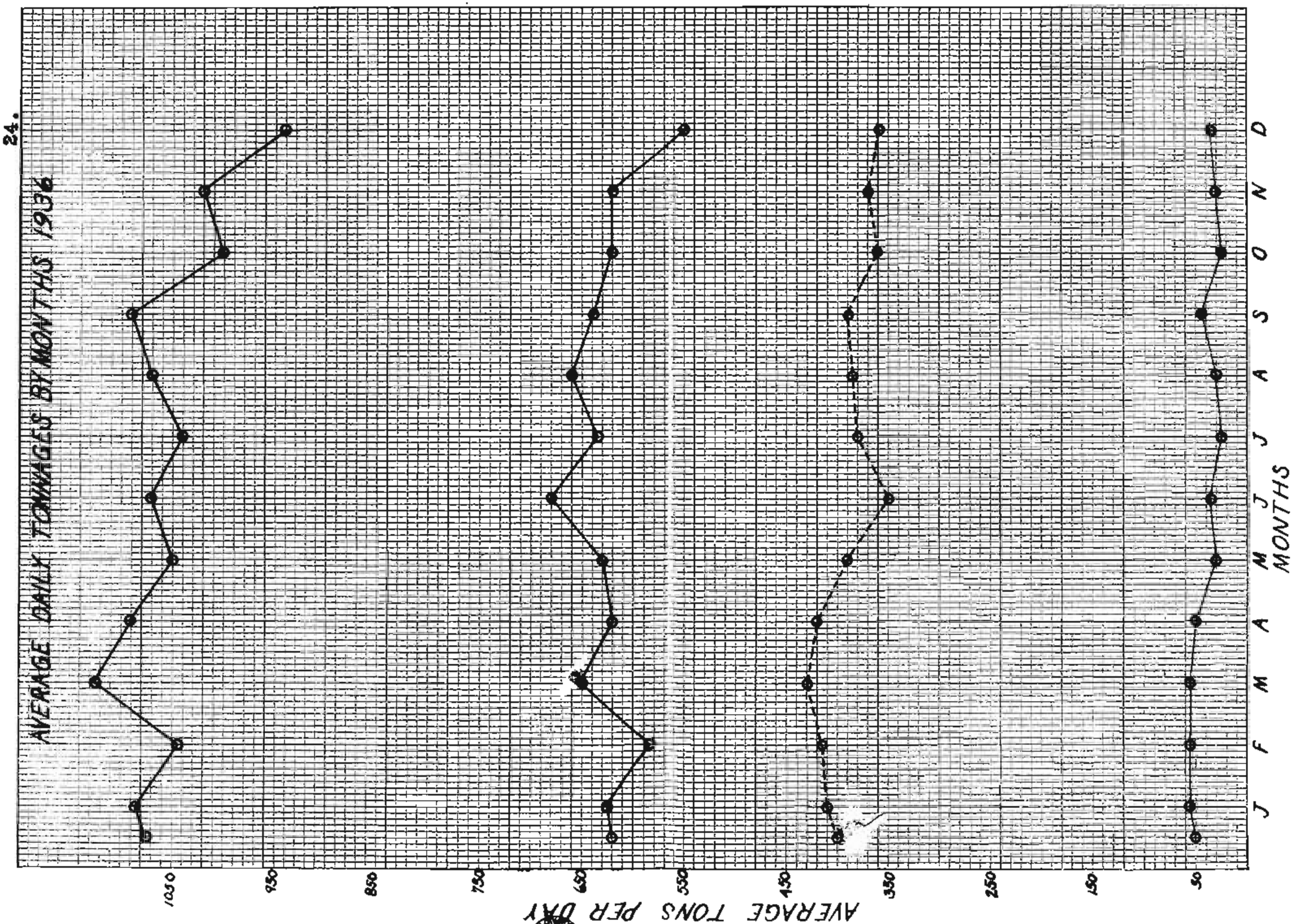

20.
COST PER FOOT DEVELOPMENT BY SECTION 1936
DOLLAR PER FOOT DEVELOPMENT
15.00 14.00 13.00 12.00 11.00 10.00 9.00 8.00 7.00 6.00 5.00 4.00 3.00
J F M A M J J A S O N D
MONTHS


21.
COSTS PER FOOT DRIFTS BY SECTIONS 1936
DOLLARS PER FOOT DRIFTS
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
J F M A M J J A S O N D
MONTHS
20 X 12 DIVISIONS PER INCH. 3114
CODEX BOOK CO., INC., NEW YORK, N. Y.

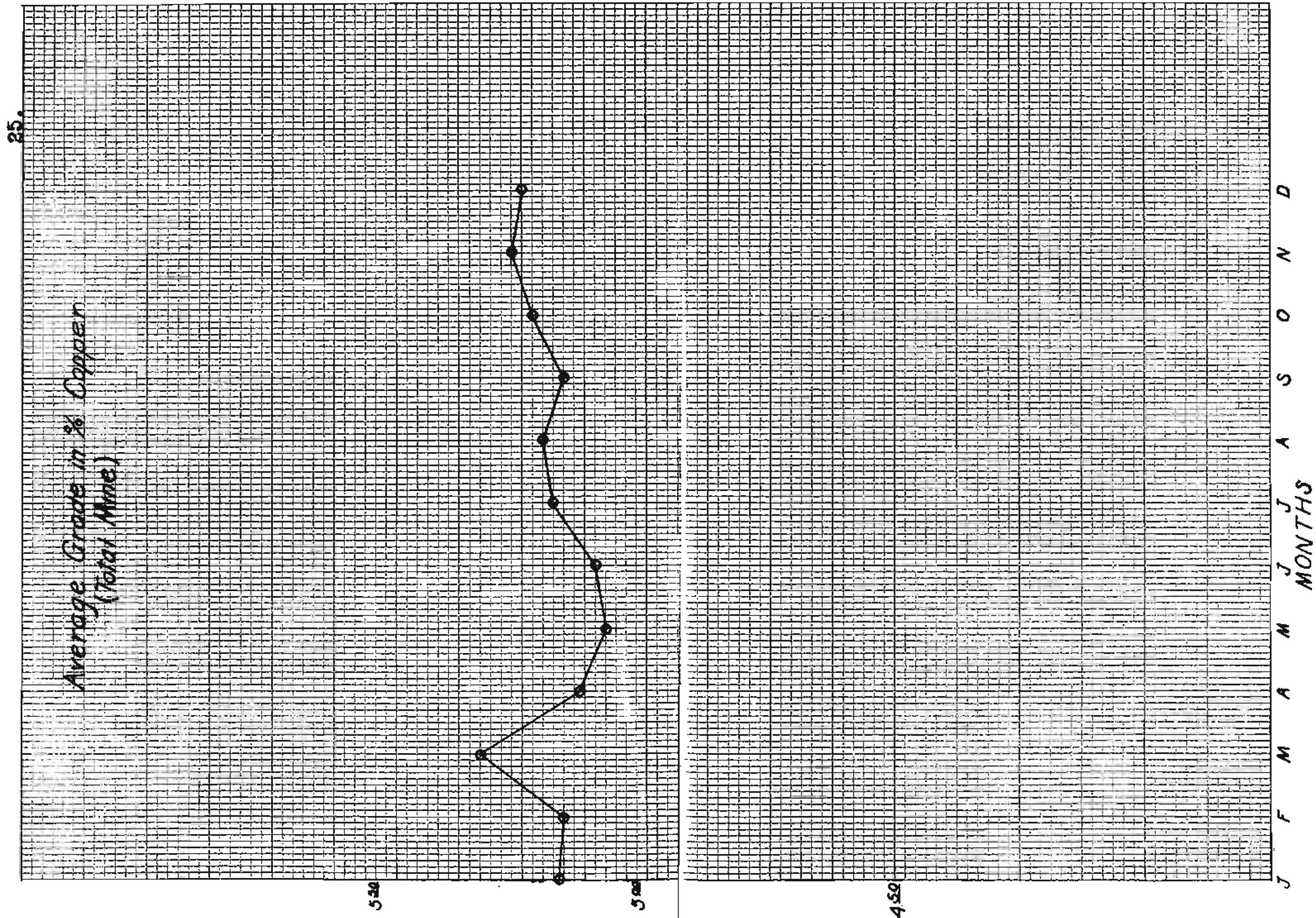
21.


22.
COST PER FOOT RAISES AND WINZES BY SECTIONS 1936
MONTHS
J F M A M J J A S O N D
Raises
Winzes
Raises
Winzes
Raises
Raises
$31.00 $30.00 29.00 28.00 27.00 26.00 25.00 24.00 23.00 22.00 21.00 20.00 19.00 18.00 17.00 16.00 15.00 14.00 13.00 12.00 11.00 10.00 9.00 8.00 7.00 6.00 5.00 4.00 3.00 2.00 1.50


TONS PER MAN SHIFT 1936
J
F
M
A
M
J
J
A
S
O
N
D
MONTHS
2.00
1.50
1.00
.50
.40
.30
.20
.10


24.
AVERAGE DAILY TONNAGES BY MONTHS 1936
J F M A M J J A S O N D
MONTHS
1050
950
850
750
650
550
450
350
250
150
50
AVERAGE TONS PER DAY

25.


25.
Average Grade in % Copper
(Total Mine)
MONTHS
J F M A M J J A S O N D
% COPPER
5.50
5.00
4.50

In order to bring this thesis up to date, the following data is included for the year 1937:

MINING COSTS: (Per Ton)	June	July
Total direct mining cost	$ 2.41	$ 2.38
Total indirect " "	.63	.60
Total mining costs	$ 3.04	2.98

OPERATING COSTS:		
Ore extraction (labor)	$15,722.00	$16,081.00
General supplies	878.00	983.00
Explosives	2,551.00	2,618.00
Lumber	4,305.00	4,381.00
Shop charges	3,232.00	3,467.00
Total ore extraction	$26,688.00	$27,530.00

DEVELOPMENT COSTS:		
Total mine (labor)	$ 8,316.00	$ 7,953.00
General supplies	1,121.00	1,553.00
Explosives	4,226.00	4,496.00
Lumber	3,382.00	4,131.00
Shop charges	3,761.00	3,856.00
Total dev. costs	$20,806.00	$21,989.00

OPERATING COSTS BY DIVISOR: (Per ton)

	June		July
Dry short tons produced	26,121		27,634
Ore extraction (labor)	$ .61	$	.58
General supplies	.03		.04
Explosives	.10		.09
Lumber	.16		.16
Shop charges	.12		.13
Total ore extraction	$ 1.02	$	1.00

DEVELOPMENT COSTS BY DIVISOR: (Per ft.)

	June		July
Feet of development	3,597		3,468
Labor	$ 2.31	$	2.29
General supplies	.32		.45
Explosives	1.17		1.30
Lumber	.94		1.19
Shop charges	1.04		1.11
Total costs	$ 5.78	$	6.34

(Per ton of ore produced; $0.79 per foot of development)